AD-A035 785 ROYAL NAVAL PERSONNEL RESEARCH COMMITTEE LONDON (ENGLAND) F/G 6/17
AIR VELOCITY AND CONVECTIVE COOLING COEFFICIENT MEASUREMENTS BE--ETC(U)
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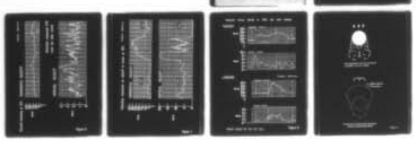

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SUMMARY

Wind speeds and convective cooling coefficients have been measured beneath a Sea King helicopter in the presence of a surface wind of 6-9 m/s (11-17 knots) on land at an air temperature of $18^{\circ}C$. Maximum air velocities generated underneath and to the side of the aircraft were found to be 9 m/s (17.5 knots) when the aircraft was on the ground and 18 m/s (35 knots) when it was hovering at a height of 15 ft. During landing and taking off, velocities as high as 33 m/s (64 knots) were recorded.

Convective cooling coefficients were found to be 43 $W/m^{2\,\circ}C$ on the ground and over 80 $W/m^{2\,\circ}C$ during hovering. These extreme losses are attributed to the highly turbulent nature of the airflow. They indicate that convective heat loss from personnel working in such air streams is likely to be at least 2-3 times the loss that would be expected from mean air speed alone.

CONTENTS

ABSTRACT

INTRODUCTION

The Environment Subcommittee of the Royal Naval Personnel Research Committee is reviewing and rationalising requirements for extreme-cold-weather clothing in ships. It is generally thought that flight-deck personnel concerned with helicopter operations in ships at sea are those most adversely affected by cold. The protection required by these crews is likely to be one of the base factors in deciding the overall extent of the clothing protection that is needed.

Flight-deck personnel can be subjected to temperatures in the range -15°C to +10°C for periods of up to 6 hours. They may be exposed to wind speeds of up to 50 knots in addition to the down-draught and outwash created by the helicopter itself. As a preliminary to land and sea trials designed to assess particular garment assemblies suitable for use in these environments, a study has been made to measure the wind strengths and convective cooling coefficients found beneath a helicopter operating on land in a temperate climate.

This paper reports the results of these experiments which were performed beneath a Sea King helicopter at A and AEE Boscombe Down on 18 September 1975.

MATERIALS AND METHODS

Apparatus. Air velocitities were measured by two electronic vane anemometers mounted on a portable steel frame. The anemometers were arranged at right angles, one to measure the horizontal airflow and the other to measure the vertical down-draught. Both anemometers were positioned at a height of 5 ft 6 in so that the air speeds measured would be similar to those experienced by a man standing underneath the aircraft. The air velocities were measured directly by the anemometers which were also coupled to a chart recorder for continuous recording of the wind-speed fluctuations.

To obtain measurements of the convective-cooling coefficients that a man might experience underneath the helicopter, a heated model representing the human body was used. This consisted of a vertical elliptical cylinder equipped with internal electrical heaters to maintain the surface at a chosen temperature. The power required to maintain the temperature of the cylinder was determined from the current and voltage supplied to the heaters. The cylinder and air temperatures were measured with electronic thermocouple thermometers. From these measurements a calculation of the convective-cooling coefficients produced by the environment was made. A sling hygrometer was used to measure ambient temperature and relative humidity. Figure 1 shows a general view of the apparatus positioned beneath the aircraft.

Air-velocity measurements. During the experiments the helicopter was facing directly into the wind. The two anemometers were placed at various positions so that measurements were made of the downflow and horizontal outwash air velocities that a man would experience when approaching the starboard side of the aircraft to reach the wheels and loading door. Measurements were made at five positions starting 47 ft from the rotor centre and ending at a position 3 ft from the loading door. Continuous recordings of the horizontal and vertical velocities were made with the aircraft on the ground and hovering at 15 ft. Recordings were also made as the aircraft took off to hover at 15 ft and also when it took off, rose vertically to 100 ft and then descended to land again. Before and after these measurements, recordings were made of the prevailing wind speed and direction.

Heat-loss measurements. The heated vertical cylinder was positioned 47 ft from the

rotor centre and allowed to reach a steady temperature. The power required to maintain this temperature was noted. During these measurements it was necessary to allow several minutes for the model to reach this steady state. Consequently, it was not possible to determine convective cooling coefficients during the landing and take off manoeuvres. For safety reasons it was not possible to make these measurements nearer to the aircraft than 47 ft from the rotor centre, that is 10 ft out from the rotor tips. This experiment was performed with the aircraft on the ground and hovering at 15 ft.

RESULTS

The prevailing wind was 6-9 m/s (11-17 knots) at 230°. The aircraft rotor speed was 100% on the ground with the torque at 19% and in the hover the speed was 102.5% and the torque 77%.

Table I shows the radial and vertical velocities together with the main velocity (calculated from $\sqrt{(\text{radial vel.})^2 + (\text{vertical vel.})^2}$) found at various distances from the aircraft in the static and in the hovering positions. These velocities are plotted in Figures 2, 3 and 4 where it is seen that the outwash wind velocity reaches a maximum at about 25 ft from the rotor centre when the aircraft was on the ground and at 38 ft when it was hovering at 15 ft.

TABLE I

Distance from rotor ft	Vertical Vel. m/s (knots)	Horizontal Vel. m/s (knots)	Mean velocity m/s (knots)
Aircraft on ground			
47	2.5 (4.9)	4.5 (8.7)	5.1 (9.9)
37	7.0 (13.6)	5.5 (16.7)	8.9 (17.3)
22	3.0 (5.8)	7.5 (14.6)	8.1 (23.4)
9	8.0 (15.5)	4.0 (7.8)	8.9 (17.3)
6	1.5 (2.9)	4.0 (7.8)	4.3 (8.4)
Aircraft hovering at 15 ft			
47	4.5 (8.7)	12 (23.3)	12.8 (24.9)
37	6.0 (11.7)	17 (33)	18 (25.0)
22	10.0 (19.4)	11.5 (22.3)	15.3 (29.7)
9	9.0 (17.5)	3.5 (6.8)	9.6 (18.6)
6	9.0 (17.5)	5.5 (10.7)	10.5 (20.4)

Figures 5 and 6 show the recordings of horizontal and vertical velocity made 47 ft from the rotor centre (10 ft out from the rotor tips) with the aircraft on the ground and hovering at 15 ft. Figure 7 shows the velocity components as the aircraft took off to hover at 15 ft and Figure 8 is a recording of the velocity components as the aircraft took off, rose vertically to 100 ft and then descended to land. The anemometer traces in Figures 5 and 6 indicate the highly turbulent nature of the downwash and outwash air streams. This

turbulence was such that flow reversal was observed when the downwash velocities were being measured. With the aircraft on the ground the mean air velocity in situations 10-40 ft from the rotor centre was substantially constant at 8-9 m/s (15.5 to 17.5 knots). During the hover, the velocity rose to reach a maximum of 18 m/s (35 knots) at about 35 ft from the rotor centre.

During the landing and take off manoeuvres velocities as high as 33 m/s (64 knots) were recorded as seen on the traces in Figs 7 and 8. The heat losses presented in Table II show coefficients as high as 80 $W/m^{2\,o}C$ when the aircraft was hovering at 15 ft and the mean airspeed around the cylinder some 13 m/s (25.2 knots).

The coefficients obtained in the absence of the aircraft were 30 $W/m^{2\,o}C$ (wind speed of 7 m/s (13.6 knots)) and those obtained with the aircraft on the ground were 43 $W/m^{2\,o}C$ (mean wind speed 5 m/s (9.7 knots)).

Heat-loss measurements. Table II shows the values of the measured-convective cooling coefficients and the mean air speed in the absence of the aircraft and then with it on the ground and hovering at 15 ft. Also shown are predicted values of the convective coefficient based on mean unidirectional wind speeds (see discussion). It is seen that the convective coefficient in the turbulent surface wind and in the absence of the aircraft is greater than predicted for a uniform wind.

TABLE II

	Measured h_c $W/m^{2\,o}C$	Predicted h_c $W/m^{2\,o}C$	Mean air speed m/s (knots)
In absence of aircraft	30	22	7 (13.6)
Aircraft on ground	43	18.7	5 (9.71)
Aircraft hovering at 15 ft	72	30	13 (25.2)

DISCUSSION

The heat losses observed in these studies are very much higher than would be expected if a human body were to be in a uniform, unidirectional wind having the same mean velocities as those that we recorded beneath the aircraft. Many workers have obtained data for forced convective heat loss from the human body and its relation to wind speed. Generally the value for the convective coefficient may be expressed by $h_c = 8.3\sqrt{V}$ (Kerslake 1972) where V is the mean wind speed. The values of the convective coefficient that would be expected from this expression are shown in Table II, where it is seen that the measured values of h_c are very much higher than predicted. There is also the anomaly of greater heat loss when the aircraft is on the ground at a wind velocity smaller than that in the absence of the aircraft.

An explanation of this is likely to be found in the highly turbulent nature of the flow. When a heated body is in a uniform air stream the flow breaks away from the body surface and a wake is formed. Associated with this flow is the heat-loss distribution shown in Figure 9.

The highest heat loss is found at the leading edge and in the wake. At the sides of the body, where the air streams break away and regions of reversed flow occur, the heat losses reach their minimum. The mean heat-loss coefficient is obtained from a graphical integration of this pattern. When the movement of the hot body is other than uniform translation, or the flow is other than unidirectional, the air-flow patterns around the body change and there is a consequent modification to the heat-loss distribution. The dependence of heat loss on the air-flow patterns has been demonstrated over the leg of a runner (Clark et al., 1974). A complex and changing air-flow pattern exists around the leg due to its swinging or 'pendulum' motion through the air.

The forced convective air-flow patterns of the front stagnation region and the trailing wake are alternately established and reversed. The result of this motion is to increase the convective heat-loss coefficient to at least twice that expected if the leg were in a uniform air stream having the same mean speed as the swinging leg.

A similar phenomenon would be expected if the heated body were stationary and the directions of the air streams changed as in a highly turbulent air flow. The frequency and amplitude of the air oscillations would be expected to dominate the convective cooling coefficients. In the present study the turbulent nature of the flow beneath the helicopter is considered to be responsible for producing the high cooling rates that have been observed. The heat transfer coefficients presented here refer to a heated vertical cylinder in a turbulent wind, and although they cannot be applied directly to the more complex case of a human subject, they may indicate the order of magnitude of the effects to be expected when the body is subjected to highly turbulent winds. The cooling coefficients found in this study, if experienced by crews working beneath operating helicopters in Arctic conditions, will produce an extremely hostile and stressful environment. Clothing for protection in these conditions will be the subject of a later study.

REFERENCES

Kerslake, D McK (1972). The stress of hot environments. Cambridge University Press, p 36.

Clark, R P Mullan, B J Pugh, L G C E and Toy, N (1974). Heat losses from the moving limbs in running; the 'pendulum' effect. Journal of Physiology, 240, pp8-9.

ACKNOWLEDGEMENTS

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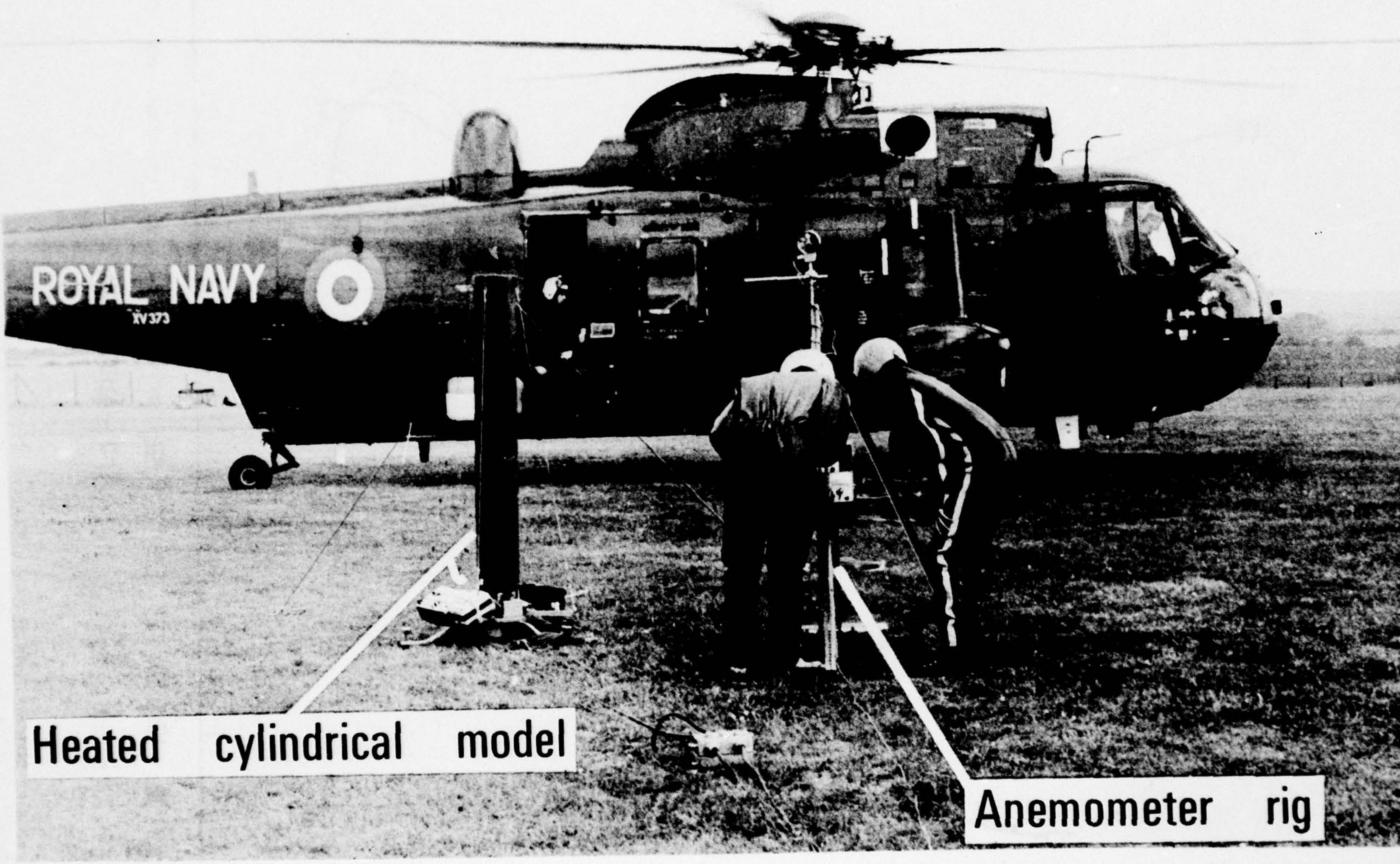
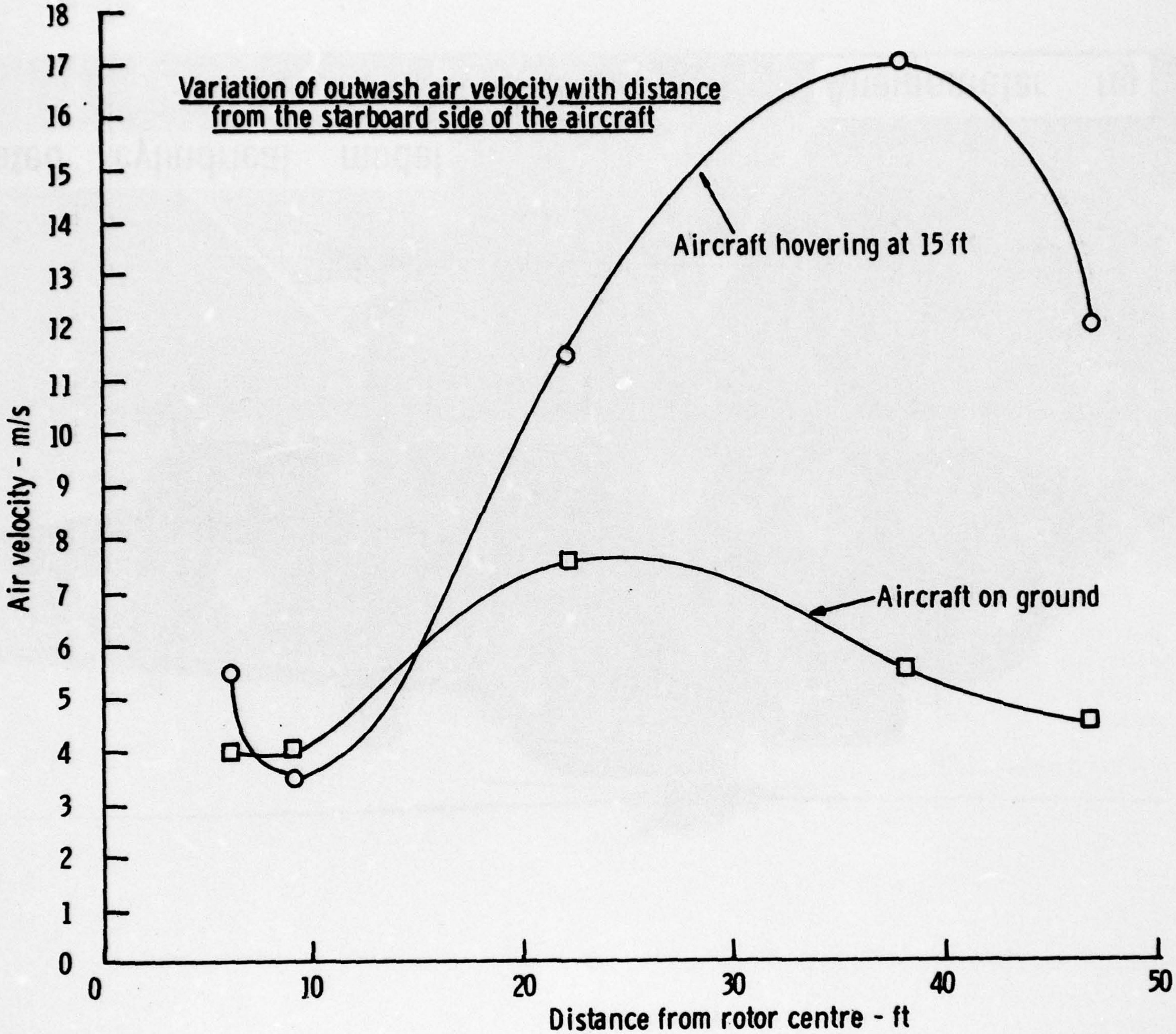


Figure 1



Variation of outwash air velocity with distance from the starboard side of the aircraft
Aircraft hovering at 15 ft
Aircraft on ground
Air velocity - m/s
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
0
10
20
30
40
50
Distance from rotor centre - ft

Figure 2

Variation of downwash air velocity with distance from the starboard side of the aircraft

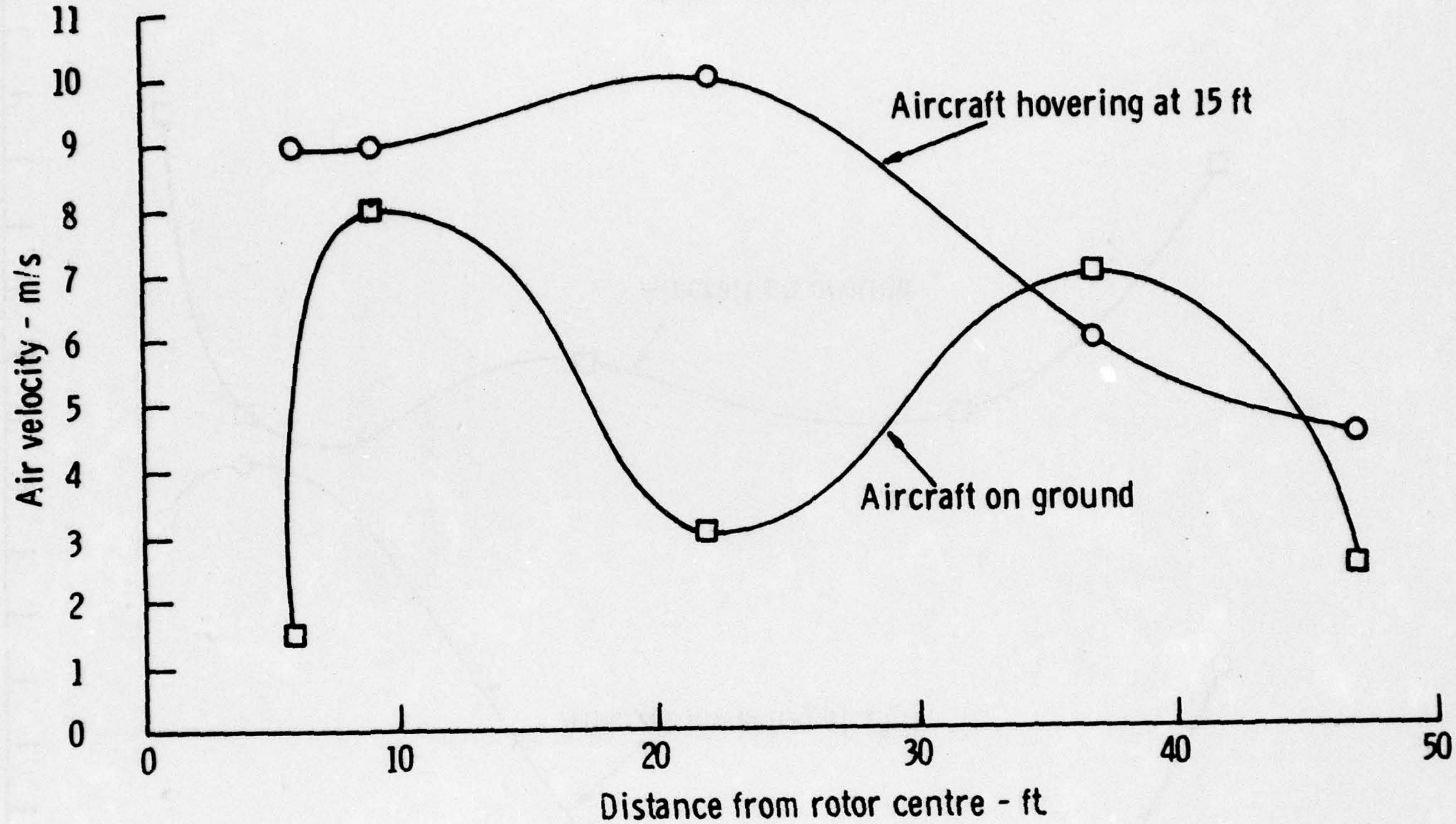


Figure 3

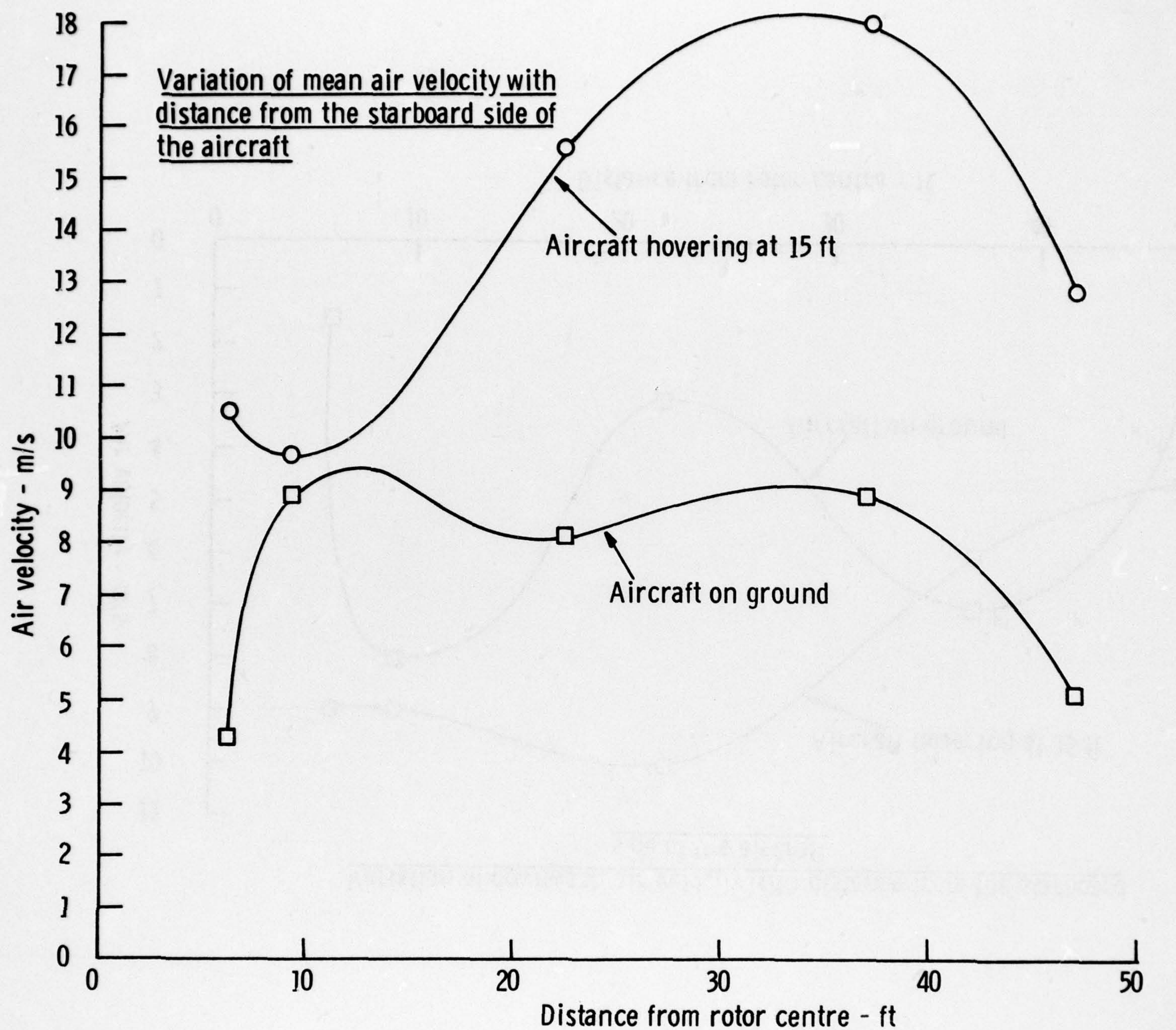

Variation of mean air velocity with distance from the starboard side of the aircraft
Aircraft hovering at 15 ft
Aircraft on ground
Air velocity - m/s
Distance from rotor centre - ft
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
0
10
20
30
40
50

Figure 4

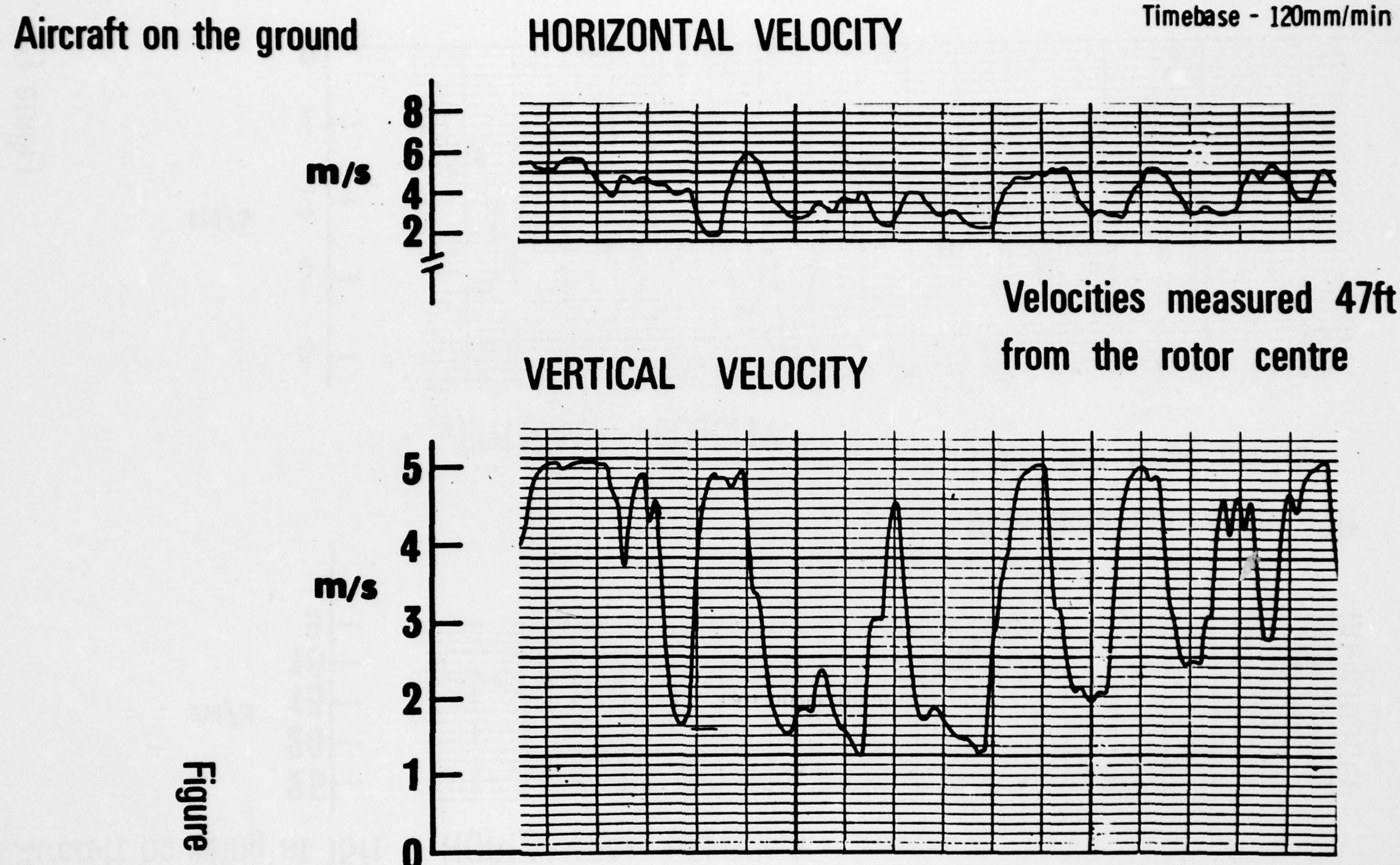
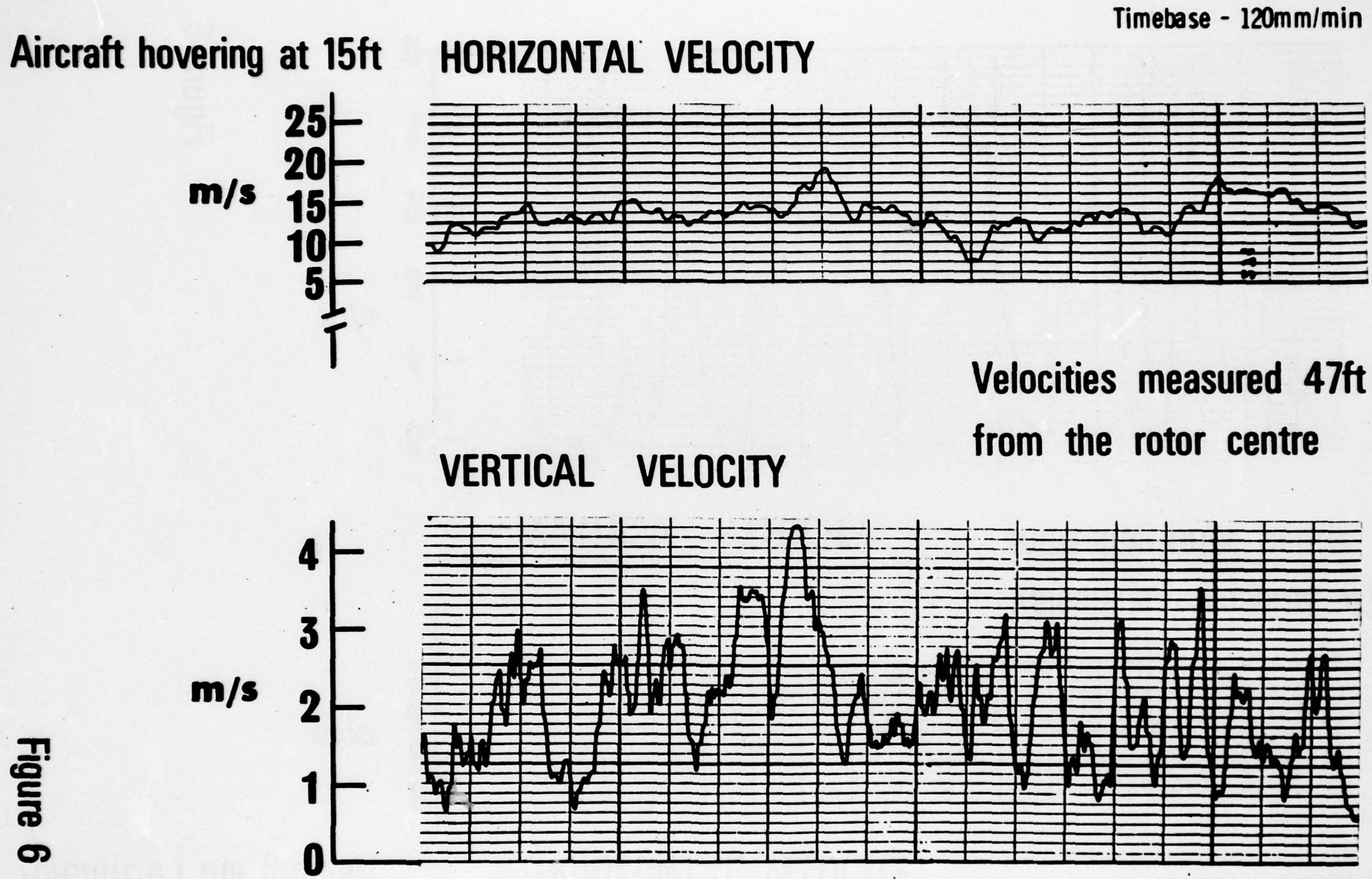

Aircraft on the ground
HORIZONTAL VELOCITY
Timebase - 120mm/min
m/s
8
6
4
2
Velocities measured 47ft
from the rotor centre
VERTICAL VELOCITY
m/s
5
4
3
2
1
0

Figure 5



Timebase - 120mm/min
Aircraft hovering at 15ft
HORIZONTAL VELOCITY
m/s
25
20
15
10
5
Velocities measured 47ft
from the rotor centre
VERTICAL VELOCITY
m/s
4
3
2
1
0

Figure 6

Velocities measured on takeoff to hover at 15ft

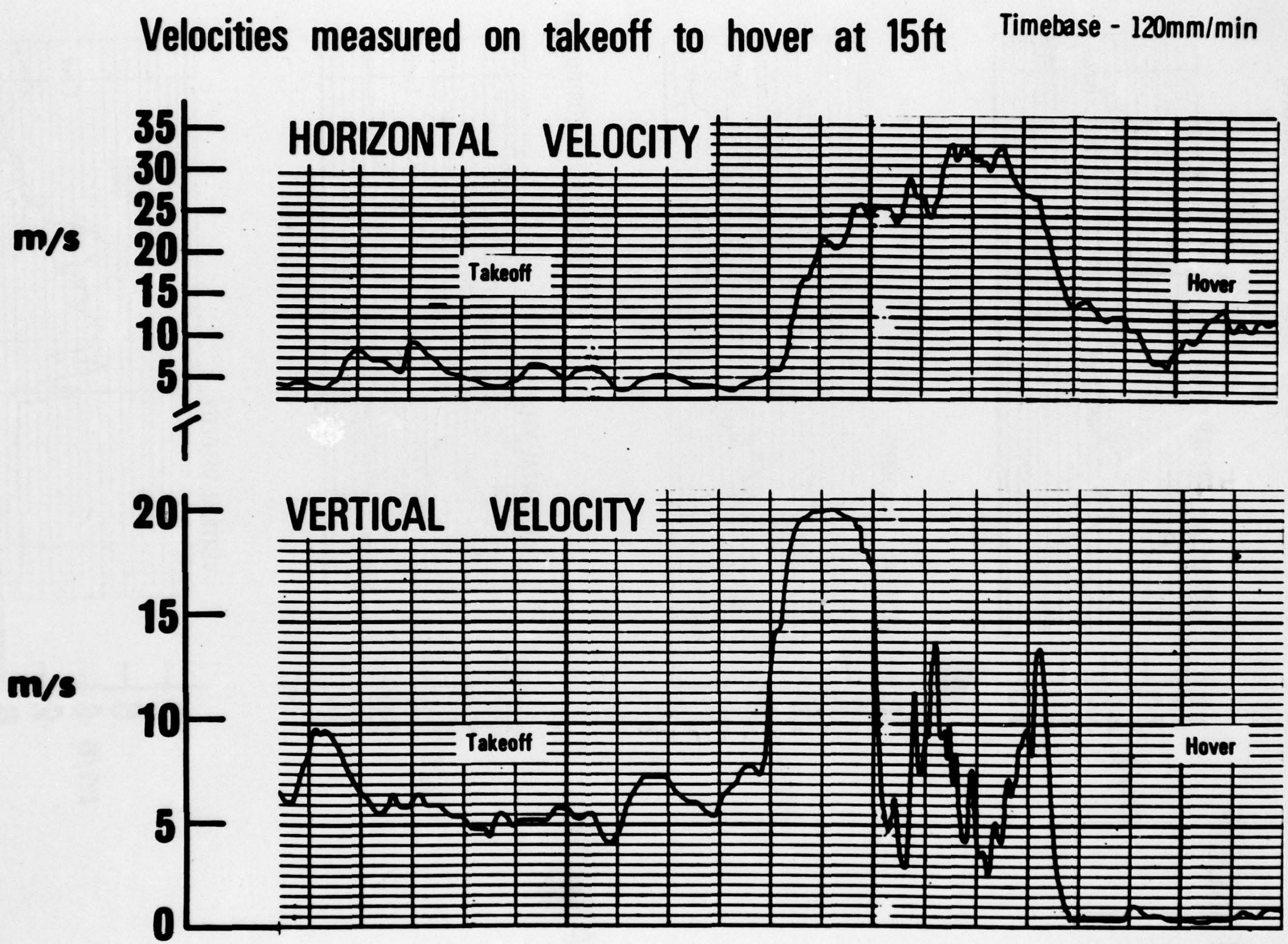
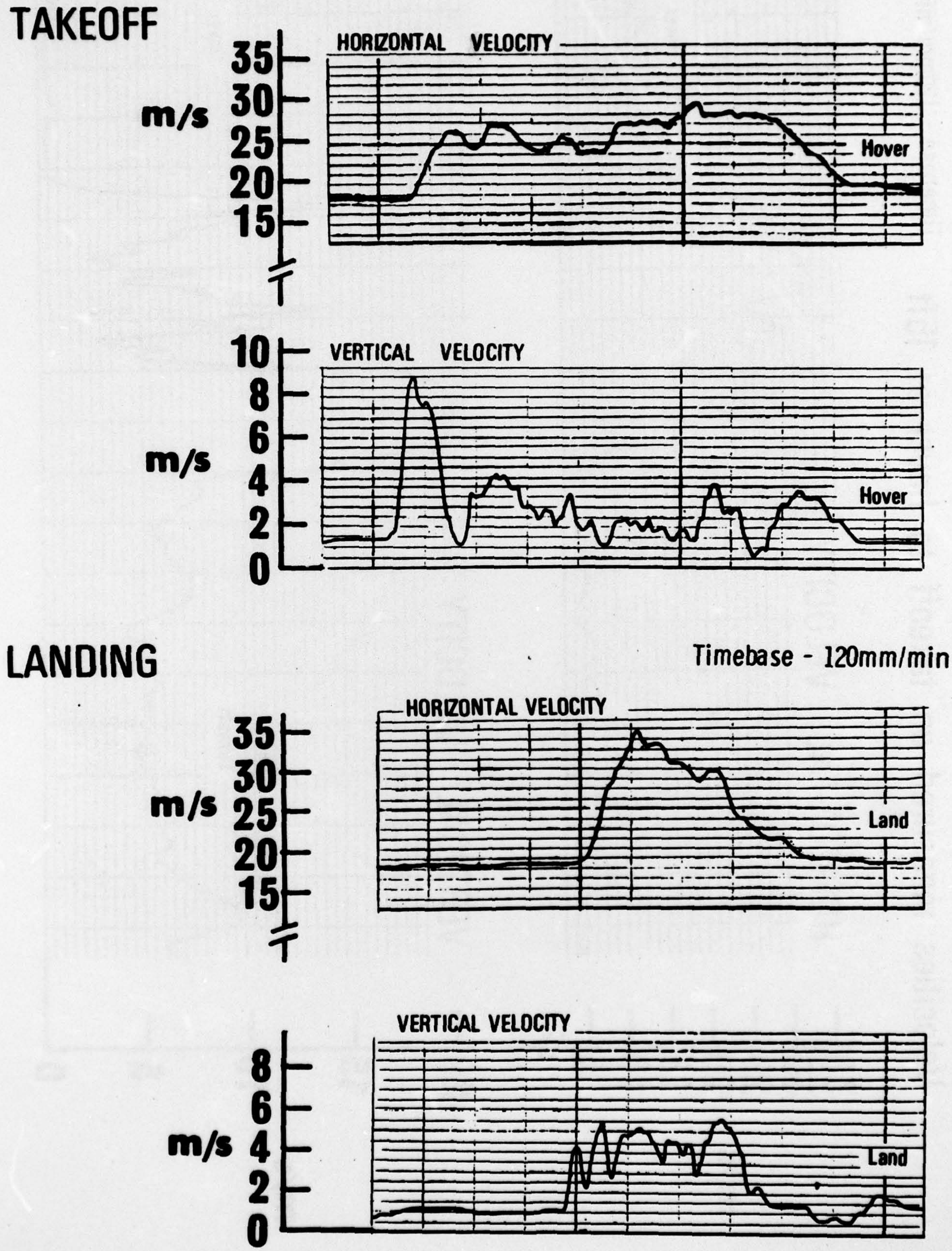


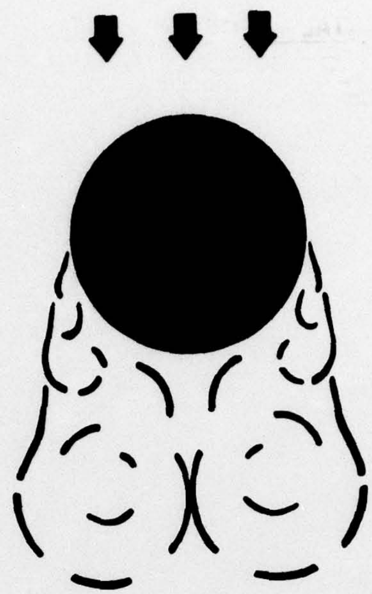
Figure 7

Velocities during takeoff to 100ft and then landing

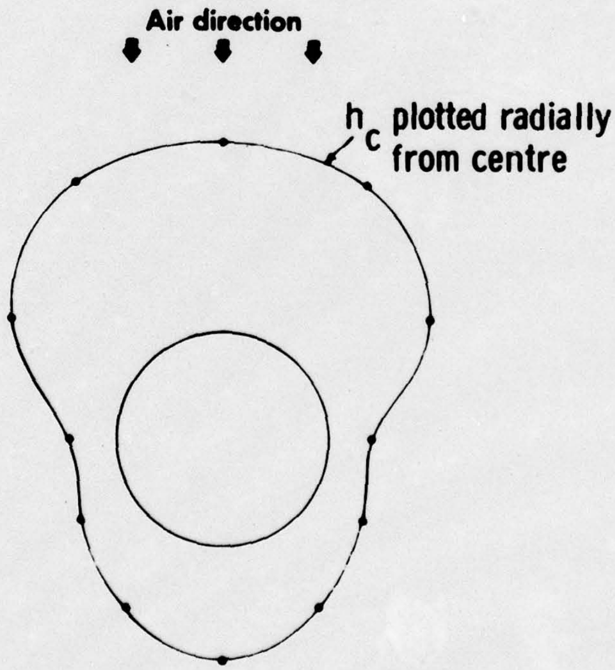


Velocities measured 47ft from rotor centre

Figure 8



Flow separation from the surface of a cylinder in an air stream



Forced convective heat transfer distribution around a vertical heated cylinder

Figure 9